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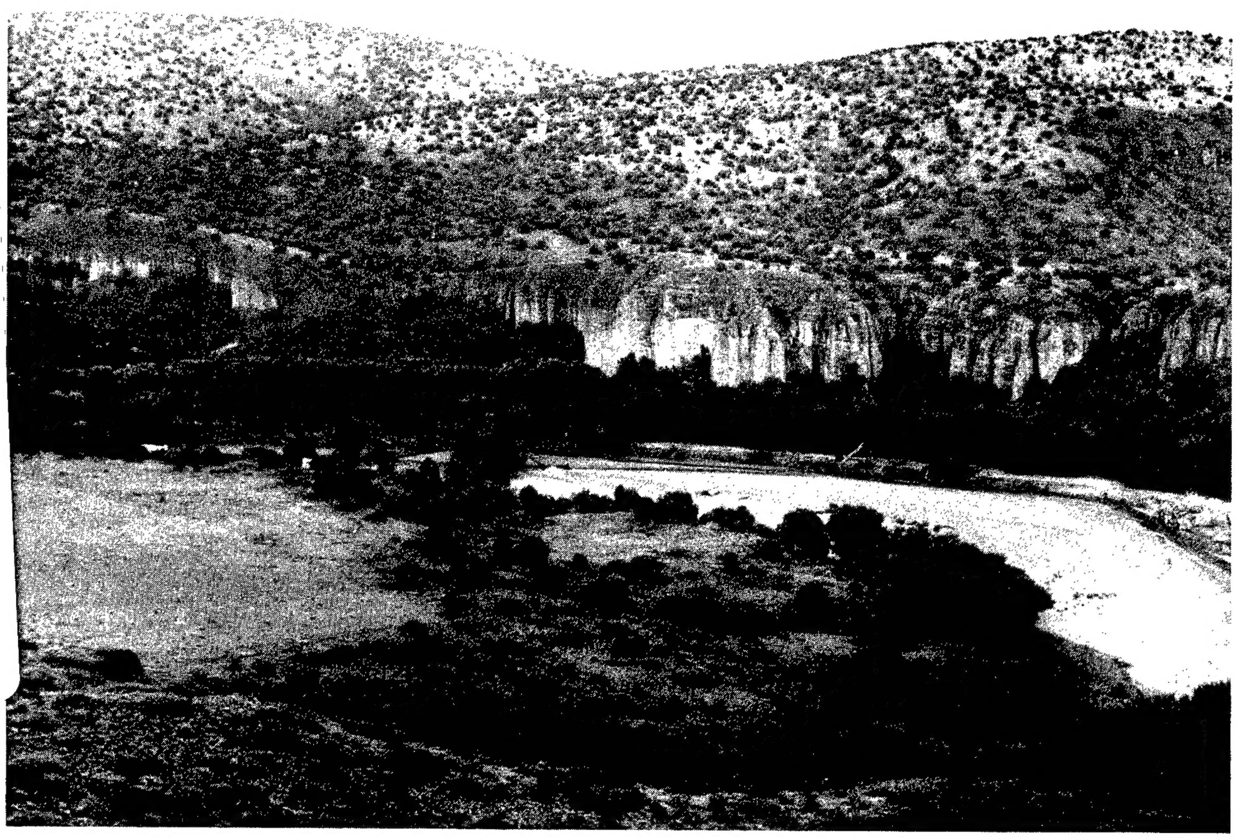

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SOIL-VEGETATION CORRELATIONS ON THE RIPARIAN ZONES OF THE GILA AND SAN FRANCISCO RIVERS IN NEW MEXICO

by

William A. Dick-Peddie
Joanne V. Hardesty
Estaban Muldavin
and
Barbara Sallach
Department of Biology
New Mexico State University
Las Cruces, NM 88003

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Project Officer

Charles Segelquist
National Ecology Center
U.S. Fish and Wildlife Service
Drake Creekside Building One
2627 Redwing Road
Fort Collins, CO 80526-2899

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

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PREFACE

The National Ecology Center of the U.S. Fish and Wildlife Service (FWS) is supporting a series of field research studies to document relationships between hydric soils and wetland vegetation in selected wetlands throughout the United States. This study is one of that series. It is a continuation of the FWS effort, begun by Wentworth and Johnson (1986), to develop a procedure using vegetation to designate wetlands based on the indicator status of wetland vegetation as described by the FWS "National List of Plants that Occur in Wetlands" (Reed 1986b). This list classifies vascular plants into one of five categories according to their frequency of occurrence in wetlands. Concurrent with the development of the wetland plant list, the Soil Conservation Service (SCS) developed a National list of hydric soils (SCS 1985b). Studies supported by the National Ecology Center quantitatively compare associations of plant species, designated according to their hydric nature using the Wentworth and Johnson (1986) procedure, with the hydric nature of soils according to their designation on the SCS hydric soils list. The studies are being conducted across moisture gradients at a variety of wetland sites throughout the U.S. Several studies have been modified to obtain concommitant information on groundwater hydrology.

These studies were conceived in 1984 and implemented in 1985 in response to internal planning efforts of the FWS. They parallel, to some extent, ongoing efforts by the SCS to delineate wetlands for Section 1221 of the Food Security Act of 1985 (the swampbuster provision). The SCS and FWS provided joint guidance and direction in the development of the Wentworth and Johnson (1986) procedure, and the SCS is currently testing a procedure that combines hydric soils and the Wentworth and Johnson procedure for practical wetland delineation. The efforts of both agencies are complimentary and are being conducted in close cooperation.

The primary objectives of these studies are to: (1) assemble a quantitative data base of wetland plant community dominance and codominance for determining the relationship between wetland plants and hydric soils; (2) test various delineation algorithms based on the indicator status of plants against independent measures of hydric character, primarily hydric soils; and (3) test, in some instances, the correlation with groundwater hydrology. The results of these studies also can be used, with little or no supplementary hydrologic information, to compare wetland delineation methods of the Corps of Engineers (1987) and the Environmental Protection Agency (Sipple 1987).

Any questions or suggestions regarding these studies should be directed to: Charles Segelquist, 2627 Redwing Road, Creekside One Building, Fort Collins, CO 80526-2899; FTS 323-5384 or Commercial (303) 226-9384.

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INTRODUCTION

Natural landscapes are becoming increasingly difficult to preserve in the United States. Even ecosystems exposed to some disturbance and/or manipulation are limited and under pressure for urban, industrial, or agricultural development. Wetland systems are among those receiving the greatest pressures. Crumpacker (1984) estimates that 70%-90% of the natural riparian ecosystems in the United States have been lost to human activities. As a result it has become necessary for Federal, State, and private organizations concerned with acquisition and management of wetland systems to devise efficient and accurate techniques for the assessment of biotic and abiotic characteristics of wetland sites. Activities along these lines have greatly increased over the past several years. One example is a volume edited by Warner and Hendrix (1984) on California riparian systems ecology, which includes relationships of wetland plants with soils and abiotic features.

The U.S. Fish and Wildlife Service is one Federal agency actively pursuing the refinement of inventory technologies and methodologies for classifications and data analyses. The Service defines wetlands as follows (Cowardin et al. 1979):

> . . . transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water . . . wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year . . . The upland limit of a wetland is designated as: (1) the boundary between land with predominantly mesophytic and xerophytic cover; (2) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or (3) in the case of wetlands without vegetation or soil, the boundary between land that is flooded or saturated at some time each year and land that is not.

Hydric soils are defined by the Soil Conservation Service (1985a) as soils that in an undrained condition are saturated, flooded, or inundated long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.

Reed (1986a) compiled a list of wetland plants of New Mexico, assigning a wetland indicator number to each species based on its frequency of occurrence along the moisture gradient. Wentworth and Johnson (1986) devised a system of using these wetland indicators for the designation of wetlands.

In 1985, the U.S. Fish and Wildlife Service initiated studies to determine the degree of correlation of wetland plant indicator ratings (Reed 1986b) and the SCS hydric soils list, test the validity of the Wentworth-Johnson system, and assess the validity of Reed's species ratings. The studies include various types of wetland systems found in the United States. Our study was conducted on western riverine systems in New Mexico. Soils were classified and delineated by Mr. Jimmy M. Gass, Soils Scientist for the U.S. Forest Service in Albuquerque, New Mexico.

DESCRIPTION OF THE STUDY AREAS

We conducted this study on reaches of the Gila and San Francisco Rivers in New Mexico (Figure 1). There have been some studies of riparian vegetation on intermittent and perennial streams in this portion of New Mexico and adjacent Arizona. Glinsky (1977) described the effects of livestock grazing and stream bed erosion on the distribution and regeneration of cottonwoods and sycamores along Sonoita Creek in Arizona. Turner (1974) compiled four maps of riparian vegetation along the upper Gila River in Arizona and documented changes in channel width and vegetation composition, possibly in response to dam construction. Hubbard (1977) conducted a biological inventory of the lower Gila River valley in New Mexico. Along the Mimbres River in southwestern New Mexico, Boles (1978) identified a pattern of community and species replacement due in part to elevational change. Egbert (1981) conducted a survey of the flora and fauna of the Gila Riparian Preserve of The Nature Conservancy. Medina (1984) analyzed riparian plant communities and soils of three intermittent creeks in the Fort Bayard watershed in New Mexico. The relationships of soil physical characteristics and pedogenesis to vegetation were addressed by Brock (1985) at four sites on the Gila River and two sites on the San Francisco River in New Mexico. Community structure of riparian vegetation at three sites along the Gila River in New Mexico was analyzed by Hardesty (1986).

Many of the dominant riparian species presently occurring along the Gila and San Francisco Rivers are apparently relicts of the deciduous forests (Arcto-Tertiary Geoflora) that covered the entire area approximately 15 million years before present (Hardesty 1986). Brown (1982) stated that many present-day Southwestern riparian trees and shrubs are the same species that have been present throughout the Southwest for several million years. Dependence on the mesic riparian environment is the common bond uniting the relictual species. Henry (1981) hypothesized that the lowering of vegetational zones during the Pleistocene had little effect on riparian vegetation in the canyons and smaller mountain ranges of the Southwest. However, Hardesty (1986) felt that along the Gila River, a definite change in riparian species composition occurs over an elevational change of 100 m, and it seems likely that some of the riparian vegetation patterns along the Gila may have been affected by the 900-1200 m downward displacement of vegetational zones during the Pleistocene, as suggested by Antevs (1954).

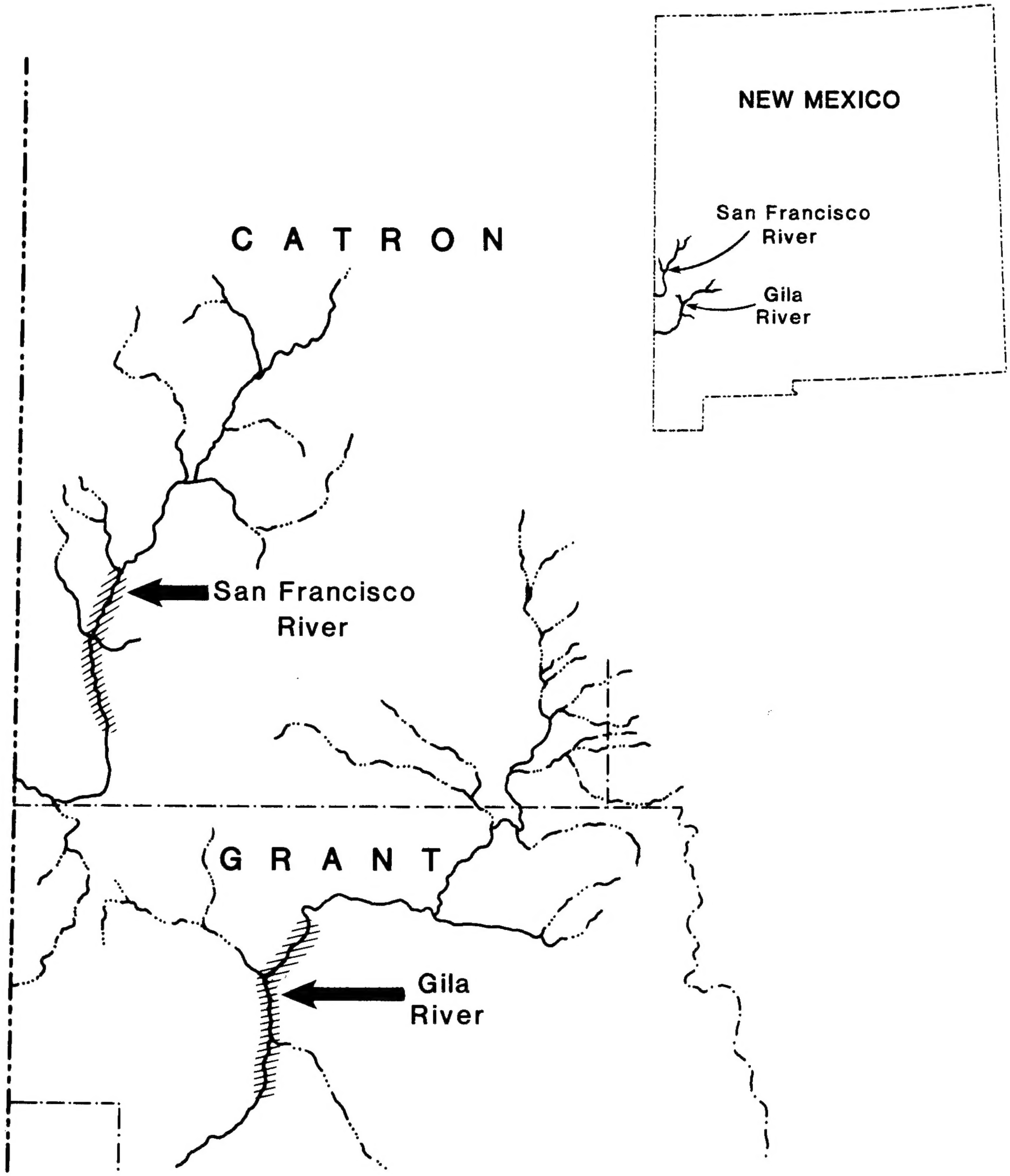


Figure 1. Locations of research areas (crosshatched) on the Gila and San Francisco Rivers.

Maker et al. (1978) indicated that most of the soils along these rivers in New Mexico are of the Haplargrids-Rough Broken Land type. The topography associated with these soils is sloping alluvial fans and terrace tops and can be very steep on upland ridges and terraces.

The general elevation of the study areas is 1500 m ± 100 m. Water temperature in the two streams averages about 21 °C, and mean annual precipitation is 350 mm. There are approximately 190 frost-free days per year, and the mean winter air temperature is 5 °C, with a summer mean of 22 °C. This description has been adapted from Monthly Climatic Summary, Office of State Climatologist, New Mexico Department of Agriculture, Las Cruces, New Mexico.

The vegetation of the reaches studied is typically subjected to periodic disturbances. These disturbances are mainly of two types: natural severe flooding from extensive steep watersheds has occurred at 15- to 20-year intervals; and, in places, there still is intensive livestock grazing along the rivers. These disturbances have resulted in much of the riverside vegetation being in various stages of succession. The type and degree of disturbance is included in the results section of this report.

METHODS

DATA GENERATION

Four dominant soils were identified along the two rivers by Gass (pers. comm.). Soils were not classified to the series level; however, hydric soils were identified based on available information at the request of the FWS. The study areas were extensive enough to permit four replications and five plots per replication on each of the soils, on each of the rivers (Table 1). Pits were dug in each soil type and a soil analysis performed. We placed five replications rather than four in lower terrace soils on both rivers, in the event that some plots in a replication should fall outside the soil class. Four extra replications were placed on the swale soils on the Gila River because there was extensive marsh area on one portion, possibly indicating a different hydric soil.

Field work was conducted during June and August of 1986. Vegetation was sampled on each of the five randomly selected plots within each replication. The field sampling technique (Table 2) followed U.S. Fish and Wildlife Service guidelines for this study. All plants were identified to species. All plants found and their frequency of occurrence index numbers, obtained from Reed (1986a), are included in the Appendix. A number of species commonly found on the plots were not on the New Mexico list (Reed 1986a). In order to analyze and compare all data from all plots, species that were not on the New Mexico list were assigned an index number based on their frequency of occurrence in this study, associations with species that were on the list, and known riparian characteristics from the literature.

Table 1. Location of replications on soil classes of the Gila and San Francisco Rivers. Numbers in parentheses represent the order that replications were sampled in the field.

Soil	Gila River				San Francisco River			
	Rep.	Range	Twnshp.	Sec.	Rep.	Range	Twnshp.	Sec.
Upper terrace (Fluventic Ustochrept)	1(11)	R17W	T17S	17NE1/4	1(20)	R20W	T11S	27SE1/4
	2(12)	R17W	T17S	17NE1/4	2(21)	R20W	T9S	27NE1/4
	3(13)	R17W	T17S	8SE1/4	3(22)	R20W	T9S	27NE1/4
	4(17)	R17W	T17S	8SE1/4	4(23)	R20W	T9S	27NE1/4
Lower terrace (Typic Ustifluvent)	1(2)	R17W	T17S	28NE1/4	1(18)	R20S	T11S	27SE1/4
	2(5)	R17W	T17S	17NE1/4	1(19)	R20W	T11S	27SE1/4
	3(10)	R17W	T17W	16NW1/4	3(24)	R20W	T9S	27NE1/4
	4(14)	R16W	T15S	6NW1/4	4(25)	R20W	T92	27NE1/4
	5(15)	R16W	T15S	6NW1/4	5(34)	R20W	T11S	4SE1/4
Sandbar (Aquic Ustifluvent)	1(1)	R17W	T17S	28NE1/4	1(35)	R20W	T11S	4SE1/4
	2(3)	R17W	T17S	16NW1/4	2(36)	R20W	T11S	4SE1/4
	3(4)	R17W	T17S	9SW1/4	3(37)	R20W	T11S	4SE1/4
	4(16)	R16W	T14S	31SE1/4	4(38)	R20W	T11S	4SE1/4
Swale (Typic Fluvaquent)	1(6)	R17W	T17S	9SW1/4	1(26)	R20W	T9S	27SW1/4
	2(7)	R17W	T17S	9SE1/4	2(27)	R20W	T9S	27NW1/4
	3(8)	R17W	T17S	21SW1/4	3(28)	R20W	T9S	27NE1/4
	4(9)	R17W	T11S	21NE1/4	4(29)	R20W	T9S	27NE1/4
					1(30)	R20W	T10S	8SW1/4
					2(31)	R20W	T10S	8SW1/4
					3(32)	R20W	T10S	8SW1/4
					4(33)	R20W	T10S	8SW1/4

DATA ANALYSIS

Weighted averages for each life-form stratum within each plot were computed using the Cornell ordination program (Gaugh 1977). The ORDIFLEX equation is:

$$W_j = (\sum_{i=1}^{p} I_{ij}\ E_{ij})/(\sum_{i=1}^{p} I_{ij})$$

Table 2. Vegetation sampling design for the Gila and San Franciso Rivers.

Stratum name	Stratum identifier	Measurements	Sample units per rep. N/size
Trees	dbh >7.5cm	N individ./species dbh individuals	5/100m²
Tall shrubs	dbh ≤7.5cm ht. >1.3m	N individ./species N leaders/individ.	5/4m²
Short shrubs	ht. >0.5m to ≤1.3m	N individ./species	5/4m²
Ground cover	ht. ≤0.5m (woody) all herbaceous sp.	% classes (Daubenmire 1968)	10/0.5m²

where W_j = weighted average for a plot within replication

I_{ij} = "importance" value for species "i" in plot "j," where the importance value is dbh quantity for tree stratum, density for shrub strata, and % cover class for ground cover stratum

E_{ij} = frequency of occurrence index number by species

p = number of species in a stratum within a plot

Each stratum was analyzed independently, producing a maximum of four separate weighted averages for each plot within a replication. Data were analyzed by strata (life-forms), instead of combining strata, because we believe that it added important ecological information on differences among life-forms, and also better accommodated the different sampling methods used for the different strata.

An analysis of variance (ANOVA) was performed to determine if there was an overall significant difference between soil classes within each stratum and when all strata were combined. Mean weighted averages of the five plots per replication were used here instead of the pooled mean of all plots (independent of replication). For intersoil relationships, a Duncan's Multiple Range Test (DMRT) was performed to determine specific significant differences among the means within a stratum and overall. Both ANOVA and DMRT were computed using the General Linear Model (GLM) procedure provided by the Statistical Analysis System (SAS) package (Ray 1985).

The same procedure was followed to analyze the data using presence/absence data instead of importance values. The I_{ij} values in the above equation were either replaced with a "1" or "0," denoting presence or absence.

RESULTS

The floodplain land-forms of the two rivers were described by Gass (pers. comm.). A typical profile of these land-forms and the subsurface features is depicted in Figure 2. The soils associated with the floodplains of the study areas are derived from recent alluvium; most commonly Gila conglomerate. The mean annual soil temperature is approximately 13 °C.

The four floodplain soils, ranging from higher (driest) to lower (wettest), are Fluventic Ustochrept, Typic Ustifluvent, Aquic Ustifluvent, and Typic Fluvaquent; the last three were classified as hydric soils (Table 3). We have assigned nontechnical synonyms to the soils subgroup classes: upper terrace soil to Fluventic Ustochrept, lower terrace soil to Typic Ustifluvent, sandbar soil to Aquic Ustifluvent, and swale soil to Typic Fluvaquent. Water tables vary among these very deep (200 cm) soils and are reflected in their classification. The Typic Fluvaquent is associated with ponded water and an indicator of this property is the odor of hydrogen sulfide. The other two hydric soils are associated with flowing water. While the three lower soils were designated hydric, quantitative seasonal data on depth to water, soil moisture, flooding frequency, and flooding duration were not available. Thus, these hydric designations should be considered tentative and may need to be adjusted as more data become available.

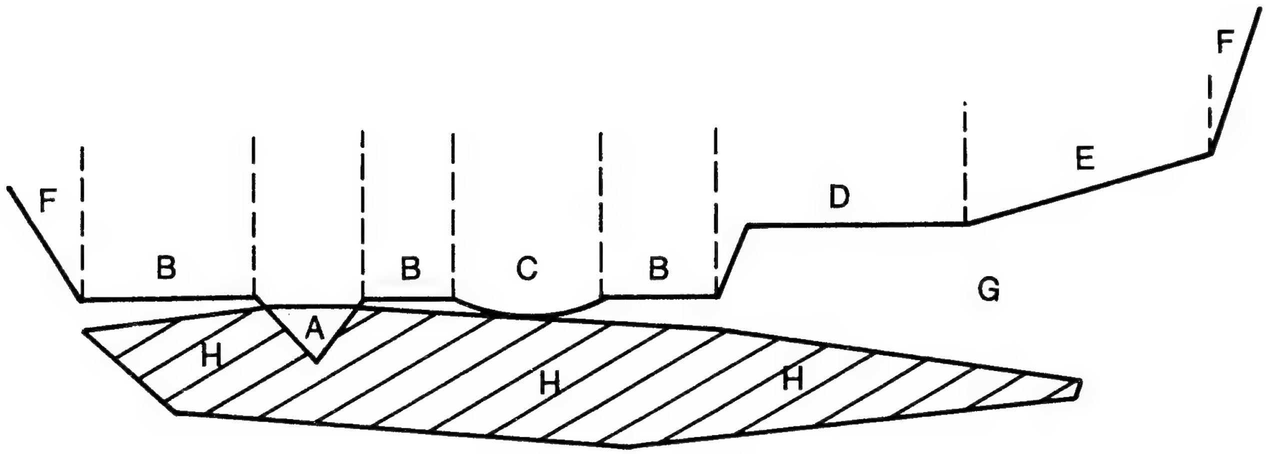
The Fluventic Ustochrept is influenced by overland flow of water but is stable enough (rarely flooded) to develop a cambic (Bw) horizon. Recharge of soil water is from direct precipitation plus overland flow. Recharge of soil water on the remaining soils is from direct precipitation, overland flow, and high water table.

Following are descriptions of the four soils:

Fluventic Ustochrept, loamy-skeletal, mixed mesic.

Pit location: T17S,R17W,SE1/4,Sec.8.Gila River.

Horizon Designation	Description
O	3 to 0 cm; litter layer of undecomposed leaves, twigs, etc.
A	0 to 9 cm; dark grayish brown (10YR 4/2) extremely gravelly sand loam, very dark grayish brown (10YR 3/2) moist; moderate fine granular structure; soft; many fine interstitial pores; common very fine roots; 75 percent rock fragments; neutral; abrupt smooth boundary.



A – Water, current channel
B – Linear sandbar
C – Concave sandbar
D – Stream terrace
E – Erosion slope
F – Gila conglomerate
G – Stream sediments
H – Water and saturated sediments

Figure 2. Generalized profile of floodplain on the Gila and San Francisco Rivers, including landforms.

AB	9 to 19 cm; grayish brown (10YR 5/2) very stony sandy loam, brown (10YR 4/3) moist; weak subangular blocky parting to weak fine granular structure; soft; many very fine and fine roots; many fine tubular pores; 60 percent rock fragments; neutral; abrupt boundary.
Bw	19 to 44 cm; dark grayish brown (10YR 4/2) very stony sandy loam, very dark grayish brown (10YR 3/3) moist; moderate medium and coarse subangular blocky structure; many very fine and fine, common coarse roots; many fine tubular pores; 50 percent rock fragments; neutral; abrupt wavy boundary.
C1	44 to 105 cm; brown (10YR 5/3) extremely gravelly sandy loam, yellowish brown (10YR 3/4) moist; massive; soft; many very fine and fine, common medium and coarse roots; many very fine and fine tubular pores; 70 percent rock fragments; neutral; abrupt wavy boundary.

Table 3. Soil and site characteristics for sample areas on the Gila and San Francisco Rivers.

Soil	Moisture regime	Temp. regime	High water table Depth (cm)	High water table Months	Flooding Freq.	Flooding Duration	Flooding Months
Fluventic Ustochrepts (upper terrace)	Ustic	Mesic	200	---	Rare	Very brief	June-Sept
Typic Ustifluvents (lower terrace)	Ustic	Mesic	150-200	Jan-Dec	Common	Brief	May-June, July-Sept
Aquic Ustifluvents (sandbar)	Ustic	Mesic	50-150	Jan-Dec	Common	Long	May-June, July-Sept
Typic Fluvaquents (swale)	Aquic	Mesic	50	Jan-	Frequent	Very long	May-Sept

2C2	105 to 160 cm; brown (7.5TR 4/2) extremely gravelly sandy loam, yellowish brown (10YR 5/4) moist; massive; soft; few medium and coarse roots; many very fine tubular pores; 65 percent rock fragments; neutral.

Typic Ustifluvent, coarse-loamy, mixed, mesic (high water table).

Pit location: T11S,R20W,SW1/4 NE1/4,Sec.4.San Francisco River.

Horizon Designation	Description
O	6 to 0 cm; litter layer of undecomposed leaves, twigs, etc.
AC	0 to 40 cm; light brownish gray (10YR 6/2) fine sand, brown (10YR 5/3) moist; single grain; loose; common very fine and

fine roots; many fine pores; laminar planes; strongly effervescent; moderately alkaline; abrupt smooth boundary.

C1	40 to 50 cm; light brownish gray (10YR 6/2) fine sandy loam, brown (10YR 5/3) moist; massive; loose; common very fine and fine roots; moderate fine and medium tubular pores; neutral; abrupt smooth boundary.
C2	50 to 127 cm; light brownish gray (10YR 6/2) fine sandy loam, brown (10YR 5/3) moist; single grain; loose, common very fine and fine, many coarse roots; many very fine and fine pores; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C3	127 to 147 cm; light brownish gray (10YR 6/2) very gravelly sand, brown (10YR 5/3) moist; massive; slightly hard; few very fine pores; strongly effervescent; moderately alkaline; 40 percent rock fragments; abrupt smooth boundary.
C4	147 to 160 cm; light brownish gray (10YR 6/2) loamy very fine sand, brown (10YR 5/3) moist; single grain; loose; few fine pores; slightly effervescent; moderately alkaline.

Aquic Ustifluvent, loamy-sketetal, mixed, mesic.

Pit location: T11S,R20W,NE1/4 SE1/4,Sec.4,San Francisco River.

Horizon Designation	Description
AC	0 to 7 cm; pale brown (10YR 6/3) cobbly loam fine sand, brown (10YR 4/3) moist; week granular structure; loose; few very fine roots; common very fine and fine pores; 15 percent rock fragments; slightly effervescent; moderately alkaline; abrupt smooth boundary.
2C1	7 to 33 cm; pale brown (10 YR 6/3) extremely gravelly coarse sand, brown (10 YR 4/3) moist; single grain; loose; many very fine and fine, common medium roots, 80 percent rock fragments; slightly effervescent; moderately alkaline; abrupt smooth boundary.
2C2	33 to 56 cm; pale brown (10YR 6/3) sand, brown (10YR 4/3) moist; single grain; loose; common fine and medium roots; slightly effervescent; moderately alkaline; abrupt wavy boundary.
3C3	56 to 76 cm; pink (7.5R 7/4) silty clay loam; massive; hard; common very fine and many fine and medium roots; common medium tubular pores; strongly effervescent; moderately alkaline; abrupt smooth boundary.

3C4	76 to 88 cm; pale brown (10YR 6/3) extremely gravelly sand, brown (10YR 4/3) moist; single grain; loose; few very fine and fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.
5C5	88 to 107 cm; pink (10YR 7/4) silty clay loam, brown (10YR 4/3) moist; massive; hard; common fine and medium roots; few fine tubular pores; strongly effervescent; moderately alkaline; abrupt smooth boundary.
6C5	107 to 135 cm; pale brown (10YR 6/3) extremely gravelly coarse sand, brown (10YR 4/3) moist; single grain; loose; many very fine and fine roots; common very fine and fine pores; 70 percent rock fragments; slightly effervescent; moderately alkaline; abrupt smooth boundary.
7C7	135 to 160 cm; pale brown (10YR 6/3) extremely gravelly coarse sand, brown (10YR 4/3) moist; single grain; 70 percent rock fragments; slightly efferescent; moderately alkaline; abrupt smooth boundary.

Typic Fluvaquent, loamy-skeletal, mixed, mesic.

Pit location: T10S,R20W,SE1/4,SW1/4,Sec.8.San Francisco River.

Horizon Designation	Description
A1	0 to 4 cm; light brownish gray (10YR 6/2) loam, brown (10YR 5/3) moist; weak fine platy parting to weak fine granular structure; slightly hard; many very fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.
2A2	4 to 13 cm; light brownish gray (10YR 6/2) fine sandy loam, brown (10YR 5/3) moist; weak fine granular structure; soft; many very fine roots; many very fine and fine pores; slightly effervescent; moderately alkaline; abrupt smooth boundary.
3C1	13 to 70 cm; light brownish gray (10YR 6/2) extremely cobbly sand; brown (10YR 5/3) moist; single grain; loose; many fine and medium roots; strongly effervescent; moderately alkaline; abrupt wavy boundary.
4C2	70 to 80 cm; light brownish gray (10YR 6/2) sandy loam, brown (10YR 5/3) moist; massive; common fine and medium roots; strongly effervescent; moderately alkaline; abrupt wavy boundary.

5C3 80 to 100 cm; light brownish gray (10YR 6/2) extremely cobbly coarse sand, brown (10YR 5/3) moist; single grain; loose; strongly effervescent; 80 percent rock fragments; moderately alkaline.

We attempted to define the plant communities that occur within soil classes; weighted averages (WA) and reciprocal averaging (RA) ordinations were constructed using ORDIFLEX (Gaugh 1977). RA is related conceptually to WA, except rather than applying preassigned species or plot weights, the method extracts relative weights for species and plots from the importance value matrix itself, using eigenvalue analysis. The result is a simultaneous ordination of species and plots that should correspond to some identifiable environmental gradient, in this case, gradations of hydric soils. We used the species ordering provided by RA to help construct a summary frequency table (Table 4) in which species are ordered along a soil moisture gradient from upper terrace to swale, with species frequency by soil indicated. This table allows quick determination of species that have indicator value with respect to differentiating among soils. "Obligate riparian" species, those species normally restricted to riparian or riparian-like habitats, were identified using criteria of Dick-Peddie and Hubbard (1977). Recent disturbance and subsequent succession on the floodplain can be inferred (Table 4) by the high frequencies of immature tree species (underlined numbers) such as Goodding willow (Salix goodingii) and Fremont cottonwood (Populus fremontii) in the short shrub layer of the sandbar and swale soils. Netleaf hackberry (Celtis reticulata) is common on the upper terrace soil as a tree, and it also has a large number of immature individuals on this same soil, as can be seen with frequencies of 13 in the tall shrub layer, 17 in the short shrub layer, and 25, a high value, in the ground cover.

The importance value weighted averages are given in Table 5. Importance value weighted averages with analysis of variance are given in Table 6, and presence/absence weighted average analysis is presented in Table 7. Tables 5, 6, and 7 show that there is a strong correlation of high species frequency of occurrence index numbers with the drier upland soils, and the correlation continues with the lower index numbers and the progressively wetter soils.

There is little difference between the "importance value" and "presence/absence" analyses (Tables 6 and 7). Consequently, biomass information is probably unnecessary for this type of assessment. In all cases, the ANOVA's proved to have highly significant F ratios. Initially, we ran separate analyses for each river system (Gila and San Francisco), but the vegetation was so similar that pooling data to increase sample size seemed advisable.

ORDIFLEX produced eight relatively discrete plant groupings that we classified as associations. These associations were derived independently of soil classes and serve as an independent assessment of soil class wetness (Table 8). The units also could be considered community types. There was a marshy spikerush (Eleocharis montevidensis) association and a barnyard grass (Echinichloa crusgalli) association. Both of these types were found on the swale soil, as would be expected from the frequency of occurrence index numbers of the species involved. Two associations were also found on the sandbar soil. These were the sandbar willow (Salix exigua) and the Goodding willow

Table 4. Frequency of occurrence of species on various soils along the Gila and San Francisco Rivers. Values are the percent occurrence of plants per soil class. Key to species code is included in appendix.

Species code	Upper terrace	Lower terrace	Sandbar	Swale
Tree layer				
QUEM	50			
JUMO	47	4		
QUAR	42			
JUMA	38R[a]	18R		
JUOS	27	4		
JUDE	27	2		
PIED	25			
FRYE	13R	8R		
CERE	10R	10R		
PRVI	7R			
QUGA	7			
ACNE	2R	8R		
MOMI	2R			
JUSC	2			
POFR		62R	22R	
SAGO		50R	7R	
PLWR		18R	2R	
POAC		8R		
POAN		4R		
ALOB		4R		
GLTR		2R		
Tall shrub layer				
RHTR	25R	4R		
FONE	13R	4R		
CERE	13R[b]	12R		
HALA	13R			
PTAN	10R			
JUMO	7			
PRVI	5R			
FRYE	5		2R	
ALWR	2R			
GAWR	2R			
JUDE	2			
JUMA	2		6	
MOMI	2R			
PRGL	2R			

(Continued)

Table 4. (Continued)

Species code	Upper terrace	Lower terrace	Sandbar	Swale
SAGO		12R	40R	
BAGL		10R	30R	
SAEX		6R	45R	
JUMA		6		
ACNE		4R		
POFR		4R	60R	
PLWR		4R		
TARA		2R	2R	
AMFR		2R		
SAIR		2R	13R	
Short shrub layer				
BRCA	50R	4R		
CERE	17R	12R		
JUMO	15			
JUMA	13	8		
VIAR	13R	2R		
HALA	10R	2R		
RHTR	10R			
FONE	10R			
GAWR	7R			
FRVE	5R		2R	
QUAR	5			
JUDE	5			
PTAN	2R			
RHRA	2			
ALWR	2			
ARCA	2			
PIED	2			
PLWR		2R		
SAGO		4R	30R	23R
POFR			40R	38R
JUOS		2	2	
TARA		2R		3R
ARLU		2		
ACNE		2R		
SAIR			5R	
FONE			2R	

(Continued)

Table 4. (Continued)

Species code	Upper terrace	Lower terrace	Sandbar	Swale
Ground cover				
SIHI	52	10	7	
CERE	25R	26R		
QUAR	20			
MASP	20	4		2
BRCA	20R	4R		
SENE	15			
HALA	13			
SPORO	13	10	15	
ERIGE	10			
BRICK	10R			
GAWR	7R			
VETH	7	2	5	2
COCA	7	10	30	42
BOCU	7			
LEPID	7	10		
PRYI	7R			
MIGU	7R	2R		2R
MAYU	7	2		
VIAR	5R	2R		
LESQU	5			
JUMO	5			
PTAN	5			
PIED	5			
QUGA	5			
ERFL	5			
VIAL	5R	2R		
CONVO	5		2	
SOEL	5	8		
RHTR	5	2R		
EUAL	5	2		2
ARCA	5	4	2	
POA	2			
ERCA	2			
ERIOG	2			
FRANS	2			
GAMI	2			
FONE	2R			
JUDE	2			
JUOS	2			
PEBA	2			

(Continued)

Table 4. (Continued)

Species code	Upper terrace	Lower terrace	Sandbar	Swale
Ground cover (cont.)				
POFE	2			
QUEM	2			
DAME	2	2		
BRMA	2	4		
ARLU	2	4	2	
CHENO	2	6	2	5
TAOF	2			8
HEDEO	2			3
MEAL		16	17	7
AMAR		14	35	17
HOJU		8	2	
GAPA		6	2	
HEAN		6	15	3
SAKA		4	50	10
PAFL		4		
JUMA		4R	2R	
MESP		4	17	22
BAHY		2		
PRGL		2R		
SISYM		2		
CRTE		2	5	
GAURA		2	5	
MEOF		2	2	3
AGAL		2	2	
SPCN			20	
SAEX			17R	
MUHLE			5	
BAGL			5R	
ARSP			2	
CLSE			2	
ERPO			2	
PANIC			2	
CONVO			2	
XASA			10	48
EQAR + EQHY			13R	7R
POPE			5R	67R
SAGO			10R	23R
AGSE			2R	4R
POMO				62R
ECCR				42R
JUTE				35R

(Continued)

Table 4. (Concluded)

Species code	Upper terrace	Lower terrace	Sandbar	Swale
Ground cover (cont.)				
ELMO				33R
CECA				25R
POAN				$\underline{23}$R
RACY				22R
PORA				18
TRIFO				15
SCOL				10R
PADI				8R
RONA				7R
JUSA				7R
JUTO				7R
SEDUM				7
TRRE				7
CYPA				5R
RAAQ				5R
SCAL				3R
PHPR				3
TYDO				3R
VEAN				3R
RUCR				3R
ACNE				$\underline{3}$R
TARA				$\underline{3}$R
TRLA				3
ERME				2
EVPI				2
FRANS				2
PLMA				2
POAA				2

[a]"R" after a number indicates that the species is a riparian species as identified by Dick-Peddie and Hubbard (1977).

[b]An underline below a number indicates that the plant is an immature individual of a tree or shrub but is making a contribution to the vegetation of that layer.

Table 5. Importance value weighted averages by life-form for each soil class. Data are pooled for both rivers.

Soil	Mean	Std.Err.	N
Tree			
Upper terrace	4.44	0.141	40
Lower terrace	2.02	0.084	50
Sandbar	1.84	0.960	11
Tall shrub			
Upper terrace	3.70	0.177	30
Lower terrace	2.09	0.154	30
Sandbar	1.49	0.070	40
Swale	1.43	0.175	8
Short shrub			
Upper terrace	3.93	0.127	36
Lower terrace	2.44	0.243	25
Sandbar	1.42	0.073	36
Swale	1.71	0.030	34
Ground cover			
Upper terrace	4.23	0.139	39
Lower terrace	3.90	0.158	46
Sandbar	3.71	0.158	40
Swale	2.31	0.074	60

associations. Again, the index numbers of the dominant species were consistent with these classifications. There was a considerable amount of California brickellia (Brickellia californica) on one of the sandbar soil replications, but it was not singled out as an association because it dominated only one replication. This same species was commonly a dominant of the shrub layer in lower terrace soil communities. Fremont cottonwood and Arizona sycamore (Platanus wrightii) were segregated as mature communities on the lower terrace soil of both rivers. Lanceleaf cottonwood (Populus acuminata), Arizona alder (Alnus oblongifolia), and velvet ash (Fraxinus velutina) were common subdominants in the Fremont cottonwood and Arizona sycamore associations. The upper terrace soil supported two associations, one on each river. An Arizona white oak (Quercus arizonica) association dominated this soil on the San Francisco River, whereas the upper terrace soil of the Gila River was dominated by an Emory oak (Quercus emoryi) association. In some stands, Arizona walnut (Juglans major) was common and almost a codominant species with the Arizona white oak.

Table 6. Importance value weighted averages with analysis of variance and Duncan's Multiple Range Test of weighted averages by soils and life-forms. Figures in parentheses indicate the number of plots involved. Data points joined by lines are not significantly different.

Soil	Tree	Tall shrub	Short shrub	Ground cover	All life-forms
Upper terrace	4.44(40)	3.70(30)	3.93(36)	4.23(39)	4.11(40)
Lower terrace	2.02(50)	2.09(30)	2.44(25)	3.89(46)	2.70(50)
Sandbar	1.84(11)	1.49(40)	1.41(36)	3.72(40)	2.22(40)
Swale		1.42(8)	1.71(34)	2.32(60)	2.12(60)
ANOVA					
F Value	83.83	55.92	23.12	44.25	114.55
D.F.	2.00	3.00	3.00	3.00	3.00
Significance	.0001	.0001	.0001	.0001	.0001

DISCUSSION

We found a high correlation between hydric soils and wetland plants across moisture gradients on riparian ecosystems of the Gila and San Francisco Rivers of New Mexico. The three hydric soils all had importance value weighted average below 3 for all life forms combined (Table 6). Similar values were obtained for presence/absence weighted average analyses (Table 7). Vegetation on the nonhydric, upper terrace soils had average values over 4 by both methods of analysis. There is some question whether the lower terrace soils, with an importance value weighted average of 2.70, should be designated as hydric. Additional research is needed to determine the soil moisture relation of the lower terrace soils during the growing season, as they appear to be saturated for only brief periods. However, from our study, it would be valid to consider plant associations with lower index values as indicators of higher soil moisture, and associations with higher index values as indicators of drier soils.

Table 7. Presence/absence weighted averages with analysis of variance and Duncan's Multiple Range Test of weighted averages by soils and life-forms. Figures in parentheses indicate the number of plots involved. Data points joined by lines are not significantly different.

Soil	Tree	Tall shrub	Short shrub	Ground cover	All life-forms
Upper terrace	4.47(40)	3.77(30)	3.84(36)	4.33(39)	4.41(40)
Lower terrace	1.89(50)	2.08(30)	2.44(25)	3.72(46)	2.59(40)
Sandbar	1.82(11)	1.55(40)	1.46(36)	3.67(40)	2.25(40)
Swale		1.44(8)	1.76(34)	2.45(60)	2.25(60)

ANOVA	Tree	Tall shrub	Short shrub	Ground cover	All life-forms
F Value	22.08	60.49	71.99	53.16	123.81
D.F.	2.00	3.00	3.00	3.00	3.00
Significance	.0001	.0001	.0001	.0001	.0001

In addition to confirming a close correlation for the frequency of occurrence of species with low index numbers with hydric soils, the results of this work generally support the assignment of index numbers to New Mexico species by Reed (1986a). However, we encountered a number of species not on the New Mexico list that we believe should have an index number of 4 or lower. We assigned index numbers to those species as indicated in the Appendix. A number of those species are classified as "obligate riparian species" by Dick-Peddie and Hubbard (1987), and should be added to the State list of wetland plants for New Mexico.

Dick-Peddie and Hubbard (1977) used the term "obligate riparian" for species that are limited to riparian or pseudo riparian habitats (ditch banks, foot of talus slopes, arroyos, and intermittent streams). In the Southwest, riparian habitats may not always have hydric soil conditions, as hydric soils are defined for this study. This is particularly true of soils associated with arroyos and intermittent canyon streams. Yet the vegetation found associated with arroyos and intermittent streams is often composed of obligate riparian species, including some species, e.g., Fraxinus velutina and Tamarix ramosissima, that have been assigned hydric index numbers of 3 by Reed (1986a). The correct assignment of index number to all obligate riparian species will

Table 8. Riparian plant associations found on the four major soils of the Gila and San Francisco River floodplains.

Soil	Plant community
Upper terrace (Fluventic Ustochrept)	Arizona white oak association (San Franciso River)
	Emory oak association (Gila River)
Lower terrace (Typic Ustifluvent)	Fremont cottonwood association (both rivers)
	Arizona sycamore association (both rivers)
Sandbar (Aquic Ustifluvent)	Sandbar willow association (both rivers)
	Goodding willow association (both rivers)
Swale (Typic Fluvenquent)	Spikerush association (both rivers)
	Barnyard grass association (both rivers)

facilitate identification and management of all western riparian ecosystems, wetland and otherwise. Our assigned numbers for these species appeared to be valid in the analysis. These species are often abundant enough to dominate or codominate their layers of riparian vegetation. We suggest that the following species, and index numbers, be added to the New Mexico list: tree--*Acer negundo* (2), *Celtis reticulata* (3), and *Morus microphylla* (3); shrub--*Brickella spp.* (4); forb--*Epilobium spp.* (3), *Parietaria floridana* (2), *Polygonum ramosissimum* (3), and *Stachys coccinea* (2).

Results of the Gila and San Francisco Rivers study also suggest that some index numbers might warrant change. *Fraxinus velutina* (3) is often found on soils that are as wet as those found under *Juglans major* (2). On the other hand, in New Mexico, an index number of 2 is too low for *Juglans major*. We suggest that the *Juglans major* index number be changed to 3. The same situation exists with *Populus fremontii* (2) and *Salix gooddingii* (1). These two obligate riparian species often occur as codominants and, in New Mexico,

Goodding willow is rarely found on the highly hydric soils typified by species carrying an index number of 1. We suggest that these two species carry the same index number of 2.

Forestiera neomexicana is an understory dominant in mature cottonwood riparian "gallery" forests and should carry the same index number (2) as cottonwoods. Helianthus annuus and Marrubium vulgare are ubiquitous species that colonize disturbed sites, and these two species have broad soil moisture tolerances. As a consequence, they have little indicator value for moist soil conditions, and should carry an index number no lower than 4.

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APPENDIX

Plants found on the Gila and San Francisco Rivers with frequency of occurrence (Reed 1986a) index numbers.

Species	Code	Index No.
__Tree__		
Acer negundo	ACNE	2[a]
Alnus oblongifolia	ALOB	2
Celtis reticulata	CERE	3[a]
Fraxinus velutina	FRYE	3
Gleditsia triacanthos	GLTR	3
Juglans major	JUMA	2
Juniperus deppeena	JUDE	5[a]
Juniperus monosperma	JUMO	5[a]
Juniperus osteosperma	JUOS	5[a]
Juniperus scopularum	JUSC	5[a]
Morus microphylla	MOMI	3[a]
Pinus edulis	PIED	5[a]
Platanus wrightii	PLWR	2
Populus acuminata	POAC	2
Populus angustifolia	POAN	2
Populus fremontii	POFR	2
Prunus virens	PRVI	3[a]
Quercus arizonica	QUAR	5[a]
Quercus emoryi	QUEM	5[a]
Quercus gambelii	QUGA	5[a]
Salix gooddingii	SAGO	1
__Shrub-tree__		
Amorpha fruticosa	AMFR	2
Prosopis glandulosa	PRGL	4[a]
Ptelea angustifolia	PTAN	4
Tamarix ramosissima	TARA	3

(Continued)

Appendix. (Continued)

Species	Code	Index No.
Shrub and vine		
Aloysia wrightii	ALWR	4[a]
Aplopappus laricifolius	APLA	5[a]
Artemisia carruthii	ARCA	5[a]
Artemisia ludoviciana	ARLU	5[a]
Artemisia species	ARTEM	5[a]
Baccharis glutinosa	BAGL	2
Brickellia californica	BACA	4[a]
Brickellia fendleri	BRFE	4[a]
Brickellia species	BRICK	4[a]
Forestiera neomexicana	FONE	4
Gerrya wrightii	GAWR	4[a]
Rhus trilobata	RHTR	4[a]
Salix exigue	SAEX	1
Salix irrorata	SAIR	2
Vitis arizonica	VIAR	3
Forb		
Ambrosia artemisifolia	AMAR	4
Bassia hyssopifolia	BAHY	2
Centaurium calycosum	CECA	2
Chenopodium species	CHENO	5[a]
Cicuta douglasii	CIDO	1
Cleome serrulata	CLSE	3
Conium maculatum	COMA	2
Convolvulus species	CONVO	5[a]
Conyza canadensis	COCA	4
Croton texensis	CRTE	5[a]
Cucurbita foetidissima	CUFO	5[a]
Datura meteloides	DAME	5[a]
Epilobium adenocaulon	EPAD	3[a]
Epilobium species	EPILO	3[a]
Erigeron divergens	ERDI	5[a]
Erigeron flagellaris	ERFL	5[a]
Erigeron species	ERIGE	5[a]
Eriogonum polycledon	ERPO	5[a]
Eriogonum species	ERIOG	5[a]
Erysimum capitatum	ERCA	5[a]
Euphorbia albomarginata	EUAL	4[a]
Evolvulus pilosus	EVPI	5[a]
Franseria species	FRANS	5[a]
Fragaria species	FRAGA	3[a]

(Continued)

Appendix. (Continued)

Species	Code	Index No.
Galium microphyllum	GAMI	5[a]
Gaura parviflora	GAPA	5[a]
Guara species	GAURA	5[a]
Hedeoma species	HEDEO	5[a]
Helianthus annuus	HEAN	3
Helianthus species	HELIA	5[a]
Lepidium medium	LEME	5[a]
Lesquerella species	LESQU	5[a]
Macharanthera species	MACHA	5[a]
Marrubium vulgare	MAVU	3
Melilotus alba	MEAL	4
Melilotus officinalis	MEOF	4
Mimulus guttatus	MIGU	1
Mirabilis longiflora	MILO	5[a]
Parietaria floridana	PAFL	2[a]
Penstemon barbatus	PEBA	5[a]
Plantago major	PLMA	2
Polygonum persicaria	POPE	2
Polygonum ramosissimum	PORA	3*
Ranunculus aquatilis	RAAQ	1*
Ranunculus cymbalaria	RACY	1
Rorippa nasturtium-aquaticum	RONA	1
Rumex crispus	RUCR	2
Salsola kali	SAKA	4
Senecio neomexicanus	SENE	5[a]
Sedum species	SEDUM	3[a]
Sisymbrium species	SISYM	3[a]
Solanum elaeagnifolium	SOEL	5[a]
Solanum rostratum	SORO	5[a]
Sphearalcea coccinea	SPCO	5[a]
Stachys coccinea	STCO	2[a]
Taraxacum officinale	TAOF	4
Trifolium lacerum	TRLA	4[a]
Trifolium repens	TRRE	4
Trifolium species	TRIFO	4[a]
Urtica gracilenta	URGR	3[a]
Veronica anagallis-aquatica	VEAN	1
Verbascum thapsus	VETH	5[a]
Xanthium saccharatum	XASA	4[a]
Grass and grasslike		
Agrostis alba	AGAL	2
Agrostis semiverticillata	AGSE	2

(Continued)

Appendix. (Concluded)

Species	Code	Index No.
Bouteloua curtipendula	BOCU	5[a]
Bromus japonicus	BRJA	4
Bromus marginatus	BRMA	4[a]
Bromus rubens	BRRU	4[a]
Cyperus parishii	CYPA	2
Echinochloa crusgalli	ECCR	2
Equisetum arvense	EQAR	2
Equisetum hyemale	EQHY	2
Eragrostis mexicana	ERME	4
Hordeum jubatum	HOJU	2
Juncus saximontanus	JUSA	2
Juncus tenuis	JUTE	2
Juncus torreyi	JUTO	2
Muhlenbergia species	MUHLE	2[a]
Paspalum distichum	PADI	1
Panicum species	PANIC	3[a]
Phleum pratense	PHPR	4
Poa annua	POAN	3
Poa species	POA	5[a]
Polypogon monspeliensis	POMO	1[a]
Scripus acutus	SCAC	1
Scirpus olneyi	SCOL	1[a]
Sitanion hystrix	SIHY	5
Sporobolu contractus	SPCO	4
Sporobolus cryptandrus	SPCR	4
Sporobolus species	SPORO	4[a]
Typha domingensis	TYDO	1

[a]Plants not on Reed's (1986a) list. Frequency of occurrence index numbers assigned by the authors.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report documents the relationship between soils and vegetation in the riparian zone of the Gila and San Francisco Rivers in Southwestern New Mexico. Relationships were determined using the weighted average procedure developed by T.R. Wentworth and G.P. Johnson, North Carolina State University, for the U.S. Fish and Wildlife Service in 1986. Four soils, in order of proximity to the stream, were examined in this study; swale, sandbar, lower terrace, and upper terrace. There was a positive correlation between hydric soils and wetland plants. Herbaceous ground cover was a less sensitive indicator of hydric soils than woody shrubs and trees. Soil moisture regimes were not well-defined, thus results should be considered tentative.

17. Document Analysis a. Descriptors

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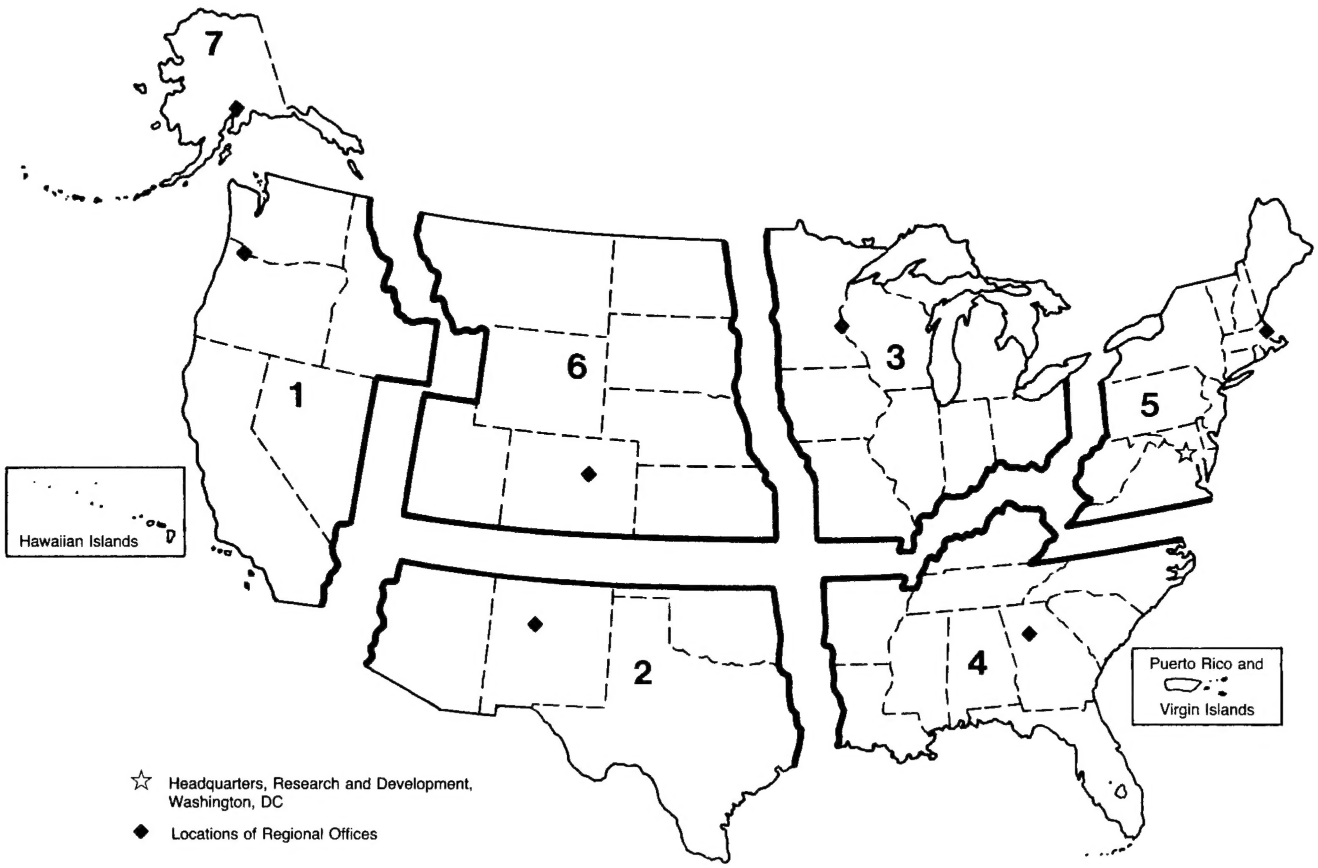

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U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

TAKE PRIDE IN AMERICA

Preserve Our Natural Resources

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.